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# United States Patent

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(54) **FUEL CELL STACK**

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Sep. 6, 2013 (JP) ................................ 2013-184873

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***H01M 8/24*** (2016.01)
*H01M 8/02* (2016.01)
*H01M 8/10* (2016.01)

(52) **U.S. Cl.**
CPC .......... ***H01M 8/2465*** (2013.01); ***H01M 8/0247*** (2013.01); ***H01M 8/241*** (2013.01); ***H01M 8/248*** (2013.01); *H01M 8/0206* (2013.01); *H01M 8/0221* (2013.01); *H01M 8/0223* (2013.01); *H01M 2008/1095* (2013.01); *Y02E 60/50* (2013.01)

(58) **Field of Classification Search**
CPC . H01M 8/2465; H01M 8/248; H01M 8/0221; H01M 8/0206; Y02E 60/50
USPC .......................................................... 429/465
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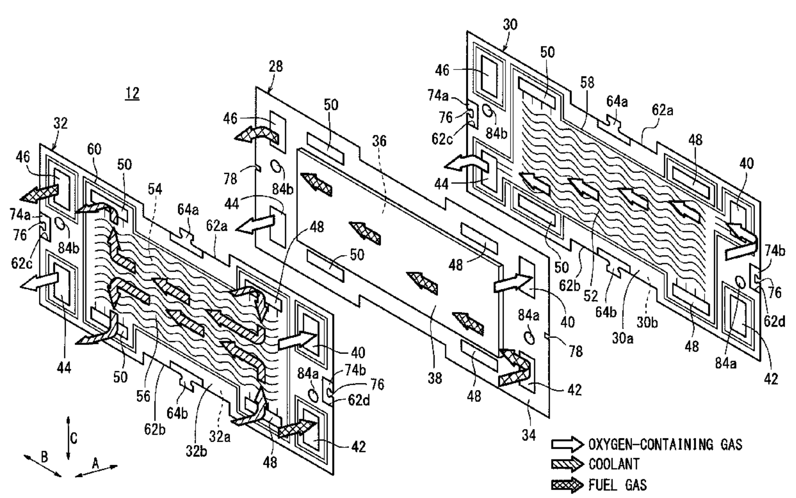
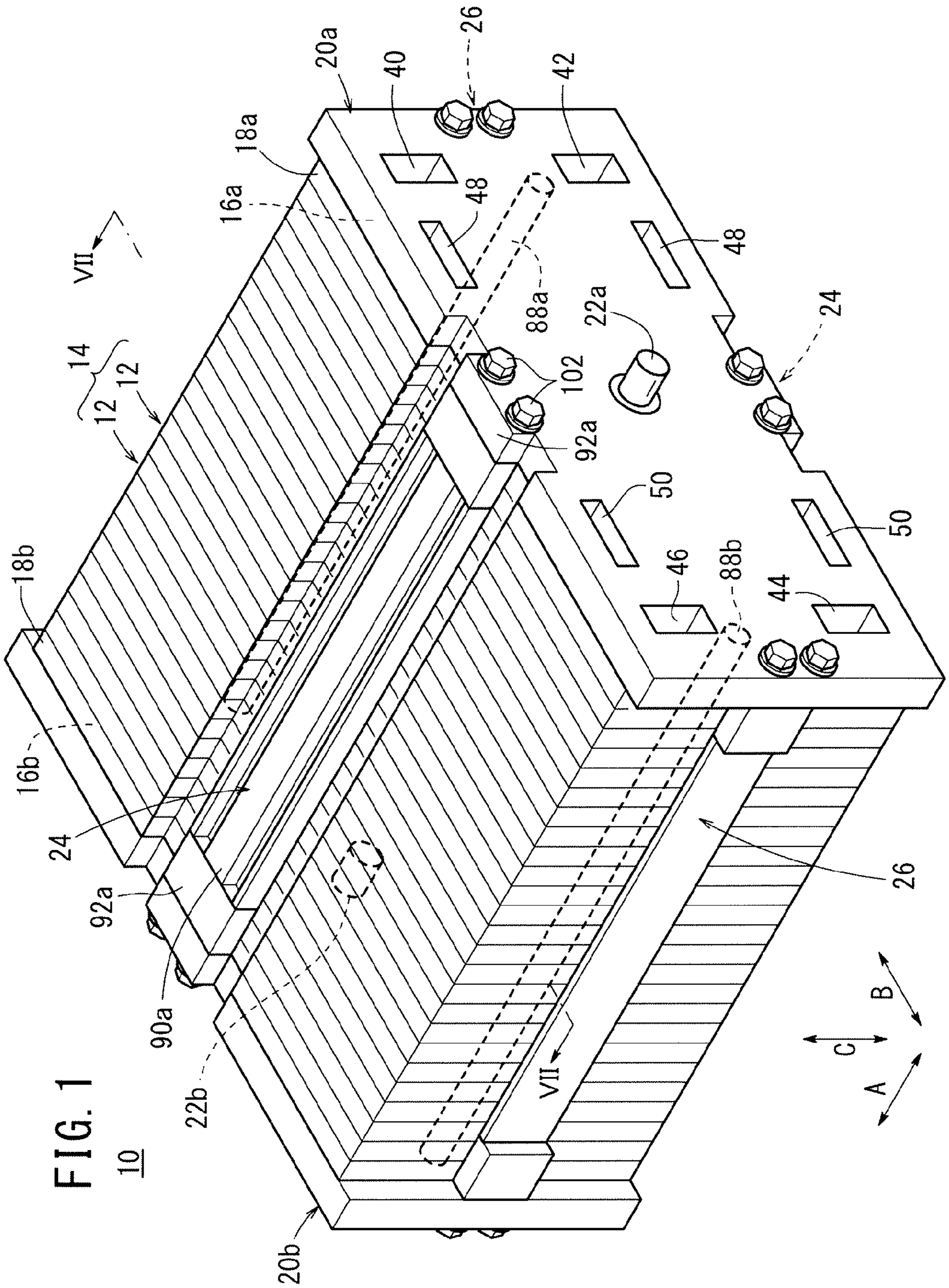
(57) **ABSTRACT**

A unit cell of a fuel cell stack includes separators. Load receivers provided in the separators include projections, for example. The proximal ends of the projections are depressed to form inner curves. In the structure, sufficient flexibility of the projection is achieved. That is, when a force in a direction perpendicular to a stacking direction of fuel cell stack is applied to the projection, the projection is deformed in the direction perpendicular to the stacking direction.

**5 Claims, 10 Drawing Sheets**

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20a
26
40
42
18a
16a
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VII
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12
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22a
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50
50
46
88b
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18b
16b
24
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90a
22b
26
VII
C
B
A
20b

FIG. 1

FIG. 2

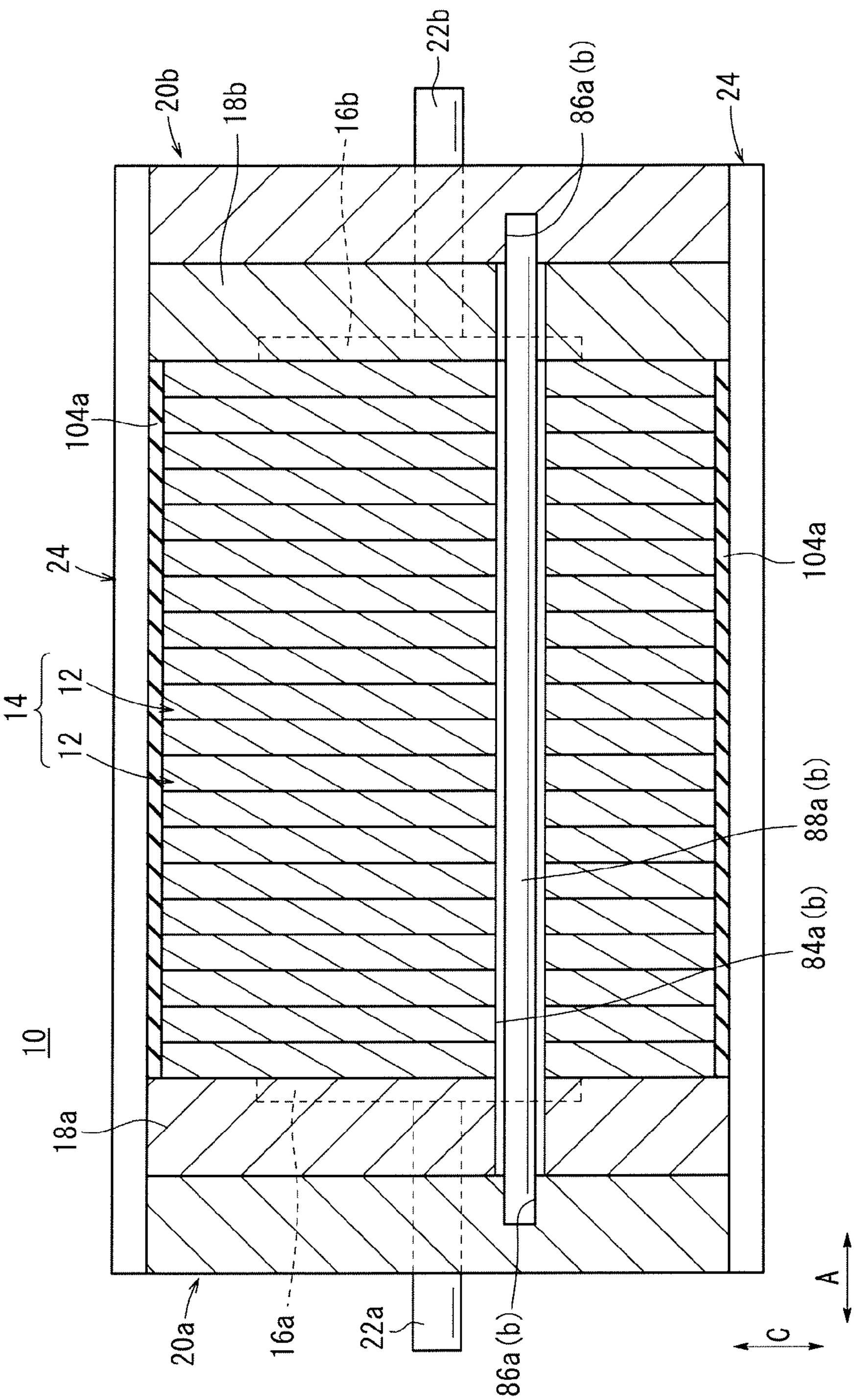
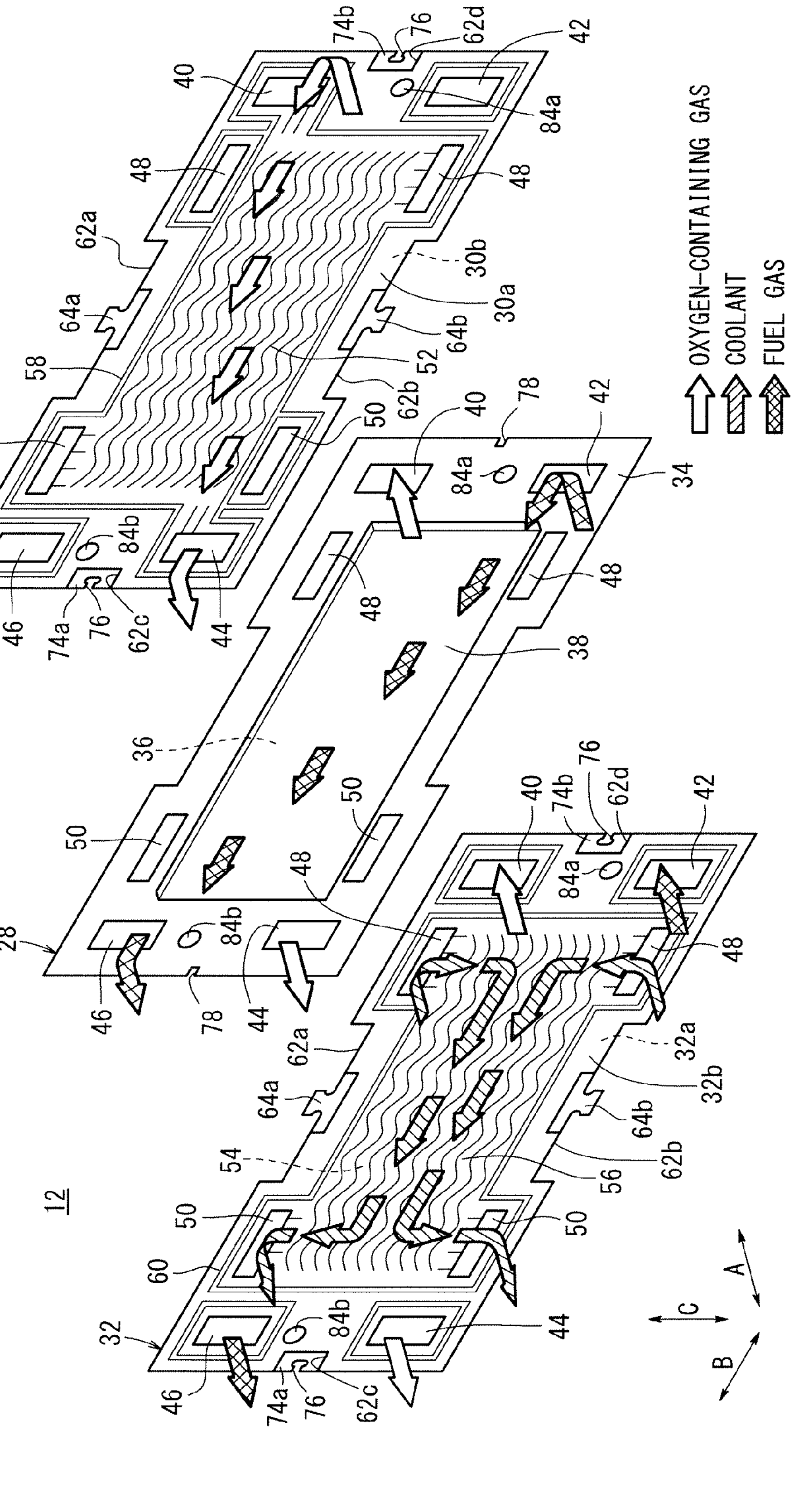

10
20b
18b
16b
22b
86a (b)
24
104a
14
12
12
88a (b)
84a (b)
18a
20a
16a
22a
A
C

FIG. 3


OXYGEN-CONTAINING GAS
COOLANT
FUEL GAS
12
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62a
62b
62c
62d
64a
64b
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74b
76
78
84a
84b
30a
30b
32a
32b
A
B
C

FIG. 4

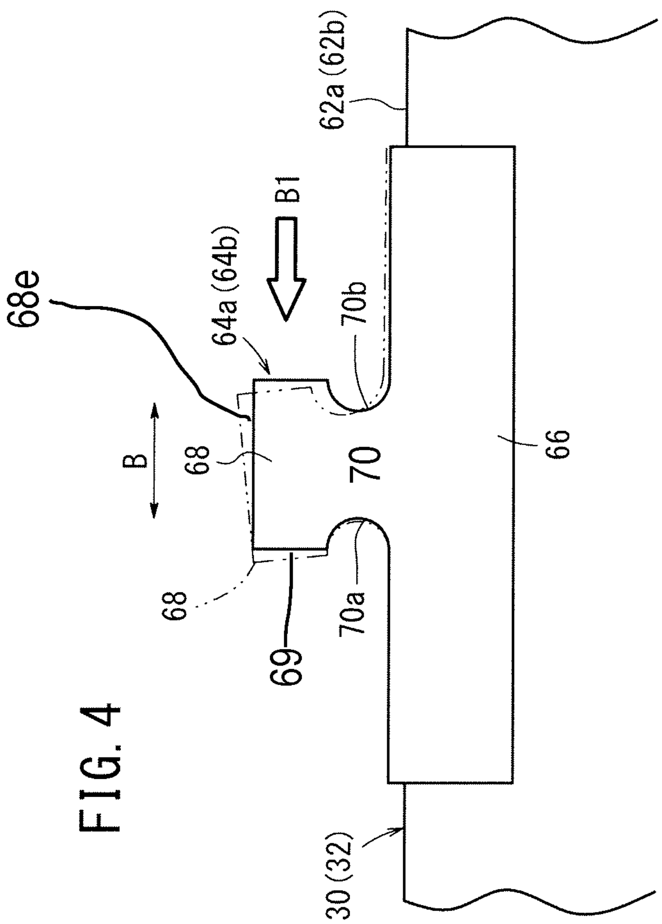


FIG. 5

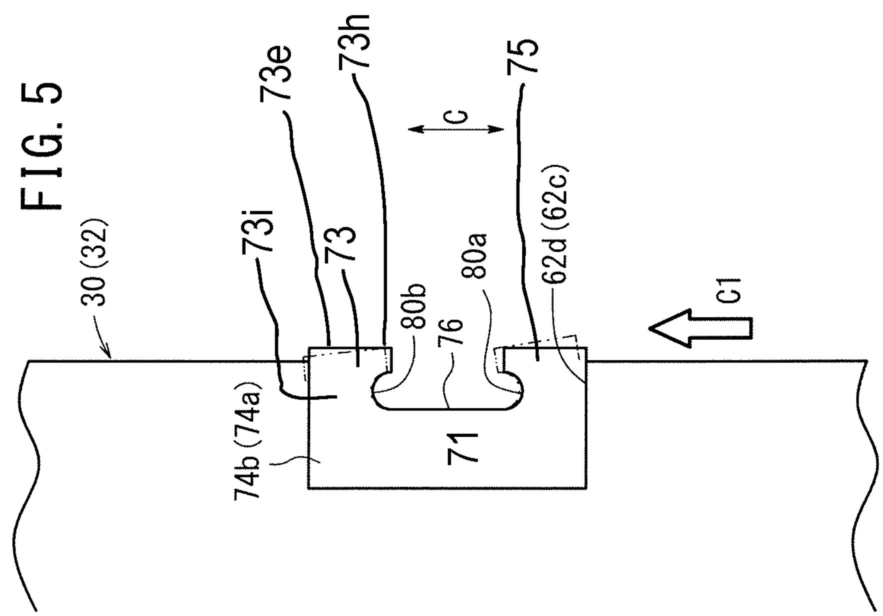
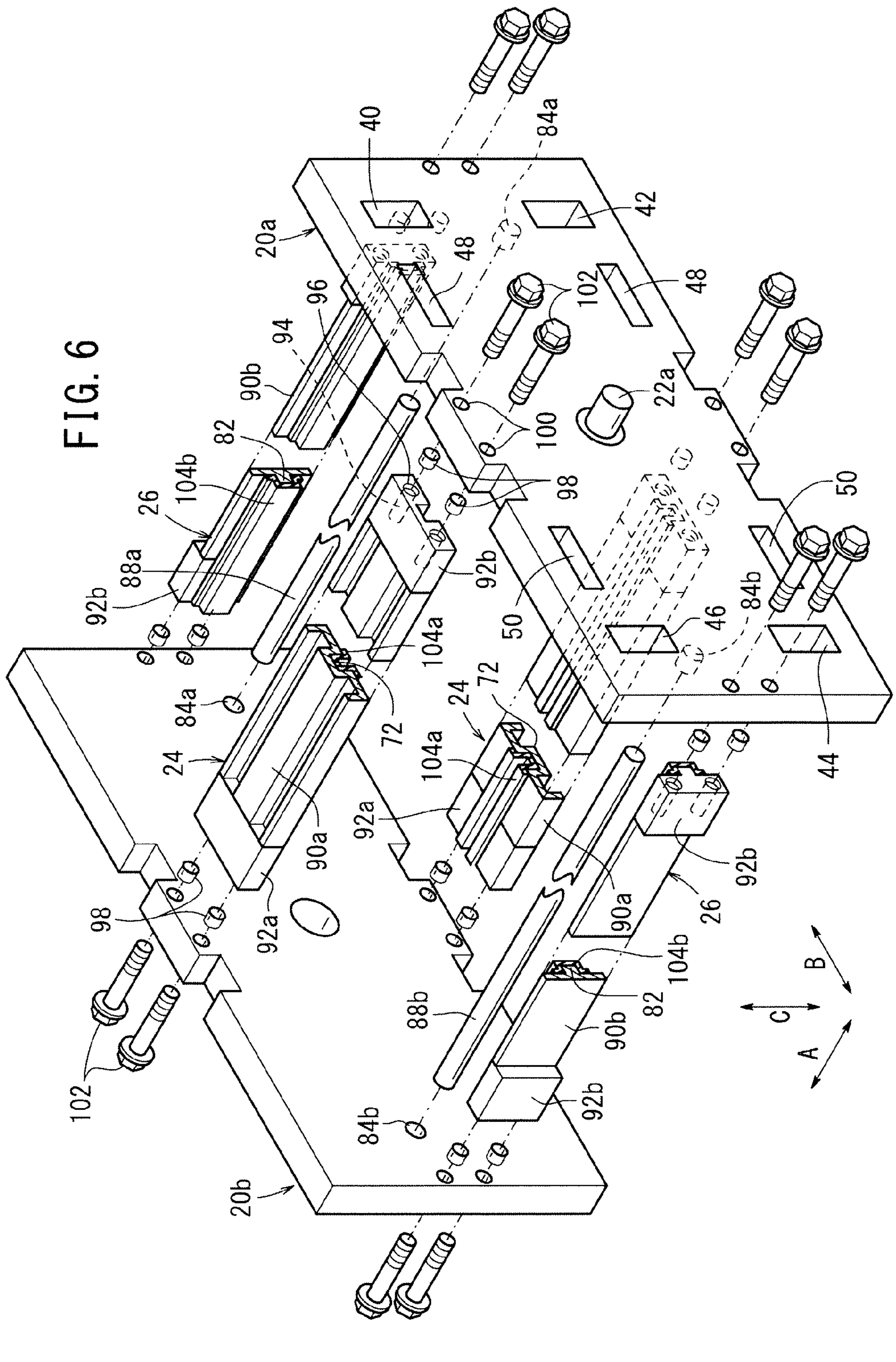


FIG. 6


40
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92b
50
84b
46
104a
72
84a
24
24
72
104a
92a
90a
44
98
92a
26
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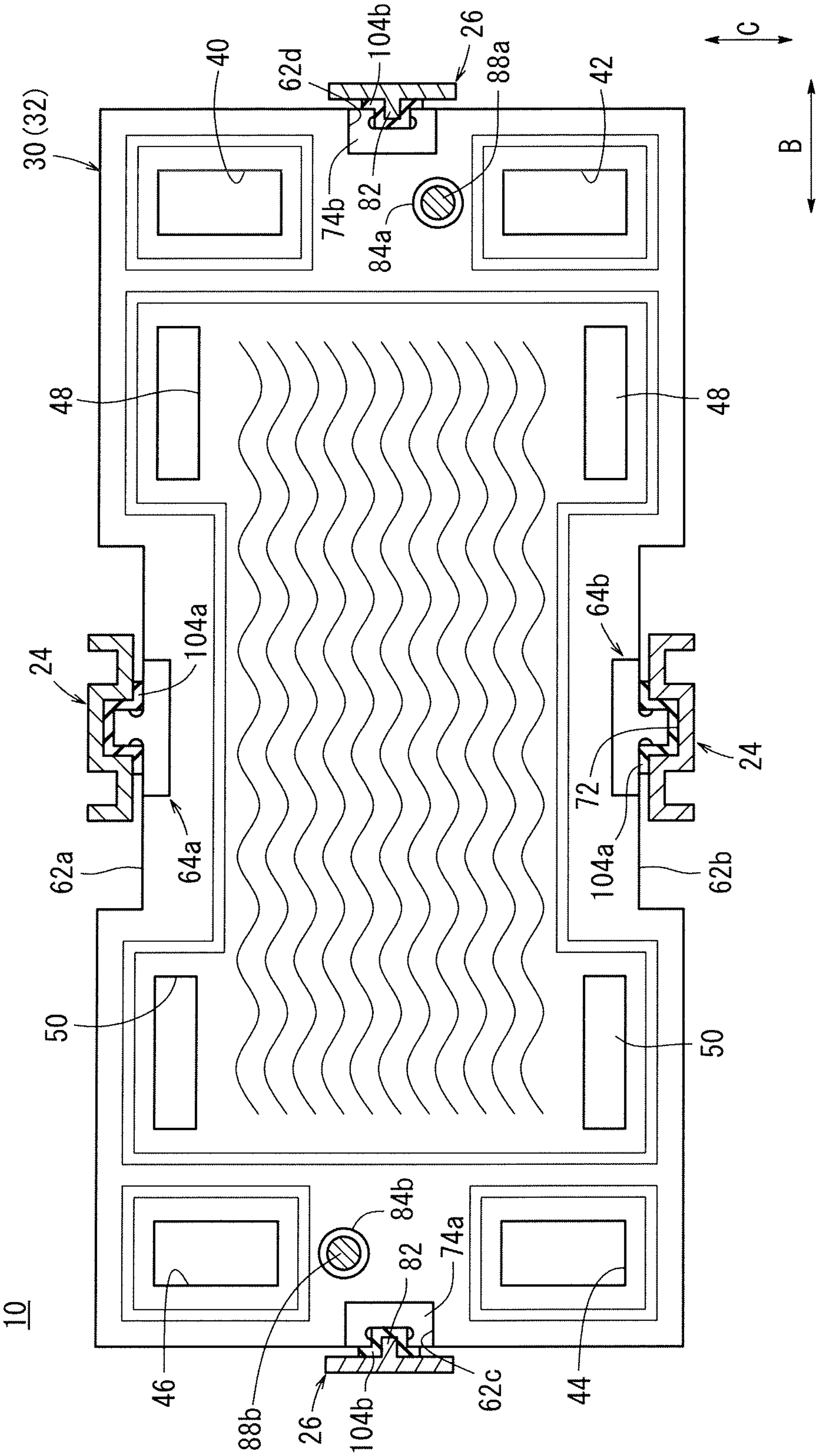
104b
88b
82
102
90b
84b
92b
20b
C
A
B

FIG. 7

10



26
104b
62d
88a
40
42
C
B
30 (32)
74b
82
84a
48
48
64b
104a
24
24
72
104a
64a
62a
62b
50
50
84b
82
74a
46
88b
26
104b
62c
44

FIG. 8

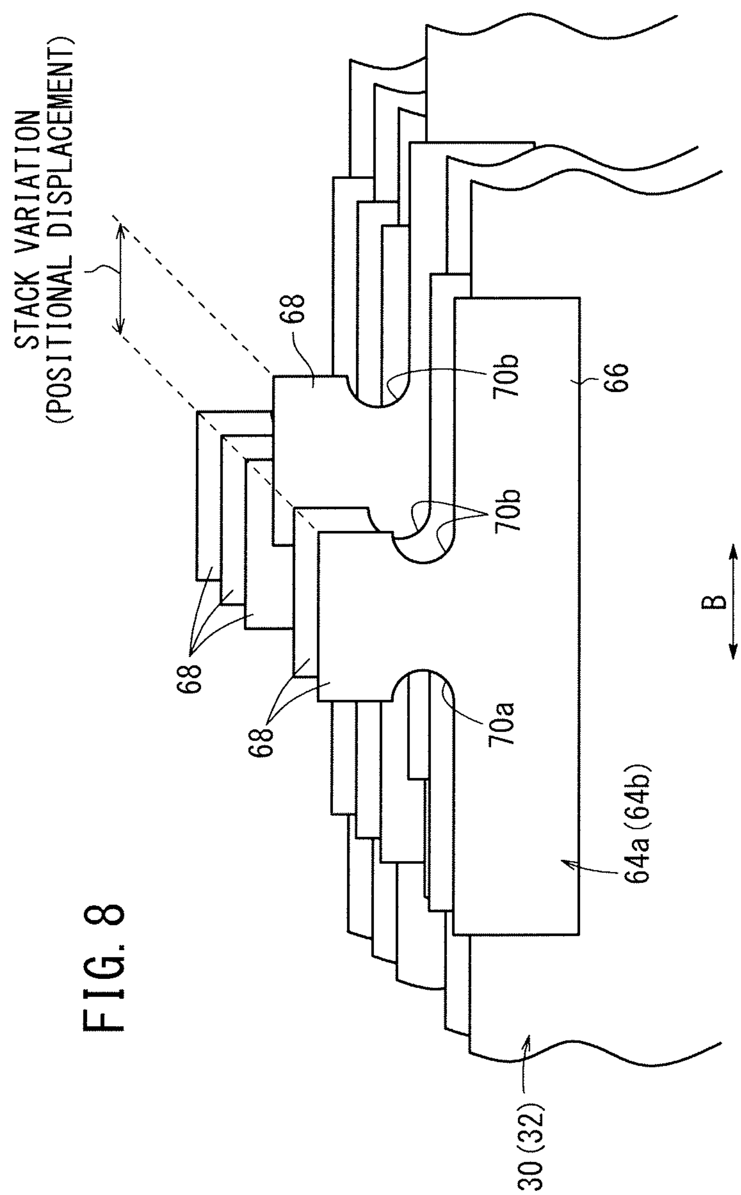

STACK VARIATION
(POSITIONAL DISPLACEMENT)
68
70b
66
70b
B
68
68
70a
64a (64b)
30 (32)

FIG. 9

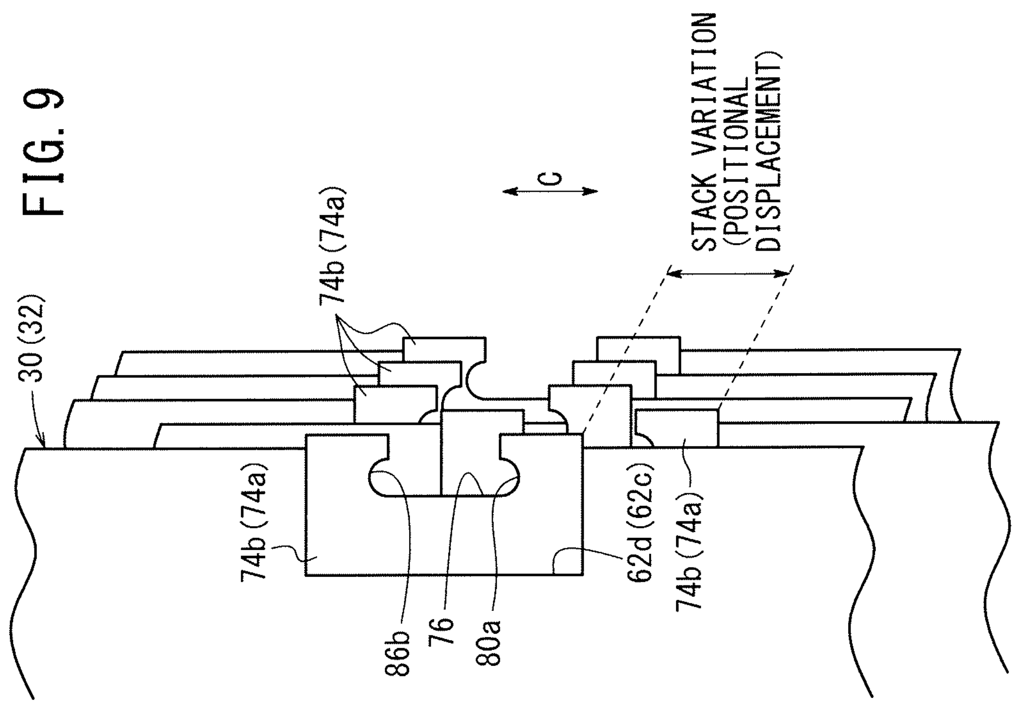
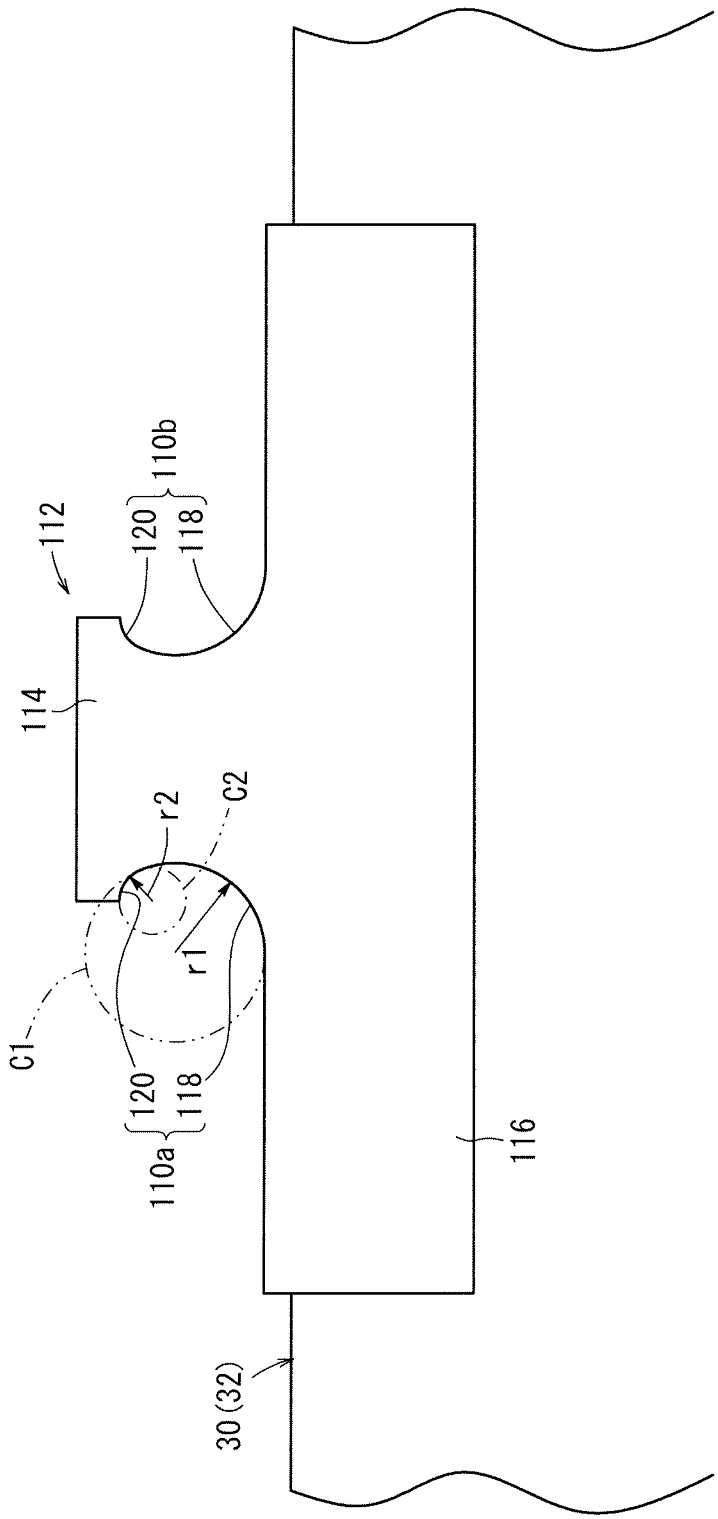

30 (32)
74b (74a)
c
STACK VARIATION
(POSITIONAL
DISPLACEMENT)
74b (74a)
86b
76
80a
62d (62c)
74b (74a)

FIG. 10



# FUEL CELL STACK

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Applications No. 2012-225720 filed on Oct. 11, 2012 and No. 2013-184873 filed on Sep. 6, 2013, the contents all of which are incorporated herein by reference.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a fuel cell stack as a stack body formed by stacking a plurality of unit cells.

2. Description of the Related Art

A fuel cell includes a unit cell formed by sandwiching a membrane electrode assembly between a pair of separators. The membrane electrode assembly includes an anode, a cathode, and an electrolyte (e.g., solid polymer electrolyte membrane or oxide ion conductor) interposed between the anode and the cathode. Normally, a plurality of the unit cells are stacked together to form a fuel cell stack. In general, in the fuel cell stack, a tightening member is provided for applying a tightening load to components between a unit cell positioned at one end and a unit cell positioned at the other end for preventing detachment of any of the unit cells.

Impact loads from the outside may be applied to the fuel cell stack of this type. As described above, the tightening load is applied to the unit cells in the stacking direction by the tightening member. Therefore, the unit cells do not move easily in the stacking direction. However, as for directions perpendicular to the stacking direction (height and horizontal directions), since no tightening load is applied, the unit cells move easily.

As a possible approach to avoid such movement, a load receiver may be provided in the outer end of the separator to absorb the impact load by the load receiver. For example, in Japanese Laid-Open Patent Publication No. 2008-027761, the applicant of the present invention proposes structure in which a fuel cell stack is placed in a casing, and load receivers provided in predetermined separators protrude to contact the inner wall of the casing.

## SUMMARY OF THE INVENTION

Ideally, separators of a fuel cell stack are overlapped in alignment with one another. However, in practice, positional displacement is inevitable, e.g., due to dimensional errors at the time of producing the separators and variation in positions of the stacked components at the time of assembling the fuel cell stack. In this case, positions of the load receivers are also displaced relatively from one another.

In this state, when an impact load is applied to the fuel cell stack, the impact load is concentrated on the load receiver having the largest positional displacement. As a consequence, the load receiver may be damaged undesirably.

A general object of the present invention is to provide a fuel cell stack in which even if positional displacement occurs in any of load receivers, since the load receivers tend to be placed in alignment with one another upon application of an impact load.

A main object of the present invention is to provide a fuel cell stack in which the impact load can be received by a plurality of the load receivers.

Another object of the present invention is to provide a fuel cell stack in which it is possible to eliminate the concern for damages of the load receivers.

In one embodiment according to the present invention, a fuel cell stack is formed by stacking a plurality of unit cells. Each of the unit cells includes an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly. The electrolyte electrode assembly includes an anode, a cathode, and an electrolyte interposed between the anode and the cathode.

The separator includes a load receiver for receiving a load in a direction perpendicular to a stacking direction of the unit cells.

The load receiver is made of resin, and has a projection protruding from an outer end of the separator or a recess depressed from the outer end of the separator.

The load receiver is depressed to form an inner curve, and the inner curve of the load receiver provides flexibility in a direction perpendicular to the stacking direction.

In the case where positional displacement occurs between any of load receivers and the other load receivers due to variation in the positions of the stacked components, the load receiver having the positional displacement protrudes beyond the other load receivers. Therefore, when a force in a direction perpendicular to the stacking direction is applied to the load receivers, this force is applied firstly to the protruding load receiver.

In this regard, in the present invention, an inner curve is formed in the load receiver to provide sufficient flexibility of the load receiver. That is, when an external force such as an impact load is applied to any of load receivers, the load receiver to which the impact load is applied is deformed easily, and placed in alignment with the other load receivers.

In the structure, thereafter, the external force is received by a plurality of the load receivers that are placed in alignment with one another. Since the external force is distributed to the plurality of the load receivers, concentration of the external force on the single load receiver can be avoided. Therefore, it is possible to prevent damages of the load receivers.

Accordingly, in the present invention, since the load receiver has the inner curve, when an external force such as the impact load is applied to the load receiver, the load receiver is deformed easily. In the case where positional displacement occurs in any of load receivers, the load receiver having the positional displacement is deformed, and placed in alignment with the other load receivers.

As a result, the external force is distributed to a plurality of the load receivers. Therefore, since concentration of the external force on the single load receiver is avoided, it is possible to prevent damages of the load receivers.

It should be noted that a tightening member extending in the stacking direction to support the unit cells may be engaged with at least one of the projection and the recess of the load receiver. In the structure, it is possible to avoid detachment of the unit cells from the fuel cell stack.

Preferably, in the case where the load receiver has the projection, radius of curvature of the inner curve is large on a side adjacent to the separator, and small on a side away from the separator. In the structure, when a load is applied to the load receiver, stress concentration tends to occur in the load receiver, at a position spaced away from the separator. Thus, when excessive stress is applied to the load receiver, the damage occurs firstly from this position.

Since the damaged position is spaced away from the separator, exposure of the separator resulting from the damage of the load receiver can be avoided. Accordingly, it is possible to avoid formation of an electrically conductive channel through the separator, and thus, it is possible to maintain the desired insulating performance.

The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which preferred embodiments of the present invention are shown by way of illustrative example.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view schematically showing a fuel cell stack according to an embodiment of the present invention as a whole;

FIG. **2** is a partial cross sectional side view showing the fuel cell stack;

FIG. **3** is an exploded perspective view showing main components of a unit cell of the fuel cell stack;

FIG. **4** is an enlarged front view showing main components by enlarging a projecting load receiver;

FIG. **5** is an enlarged front view showing main components by enlarging a recessed load receiver;

FIG. **6** is an exploded perspective view showing end plates, first tightening members, and second tightening members of the fuel cell stack;

FIG. **7** is a cross sectional view taken along a line VII-VII in FIG. **1**;

FIG. **8** is an enlarged perspective view showing main components by emphasizing positional displacement between projecting load receivers;

FIG. **9** is an enlarged perspective view showing main components by emphasizing positional displacement between recessed load receivers; and

FIG. **10** is a front view schematically showing a projecting load receiver having inner curves as a whole where radius of curvature of the inner curves is different between a side adjacent to the separator and a side away from the separator.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter a preferred embodiment of a fuel cell stack according to the present invention will be described in detail with reference to accompanying drawings.

FIG. **1** is a perspective view schematically showing a fuel cell stack **10** according to an embodiment of the present invention, and FIG. **2** is a partial cross sectional side view showing the fuel cell stack **10**. The fuel cell stack **10** is mounted in a vehicle body of an automobile (not shown), and used as a driving source for allowing the travel of the automobile. The width of the vehicle body of the automobile is indicated by an arrow A, the travel direction of the automobile is indicated by an arrow B, and the vertical direction is indicated by an arrow C.

As can be seen from FIGS. **1** and **2**, the fuel cell stack **10** includes a stack body **14** formed by stacking a plurality of unit cells **12** in the direction indicated by the arrow A. At one end of the stack body **14** in the stacking direction, a first terminal plate **16***a* is provided. A first insulating plate **18***a* is provided outside the first terminal plate **16***a*, and a first end plate **20***a* is provided outside the first insulating plate **18***a*. Likewise, at the other end of the stack body **14** in the stacking direction, a second terminal plate **16***b* is provided. A second insulating plate **18***b* is provided outside the second terminal plate **16***b*, and a second end plate **20***b* is provided outside the second insulating plate **18***b*.

A first output terminal **22***a* connected to the first terminal plate **16***a* extends from a central portion of the first end plate **20***a*, and a second output terminal **22***b* connected to the second terminal plate **16***b* extends from a central portion of the second end plate **20***b*.

Each of the first end plate **20***a* and the second end plate **20***b* has a laterally elongated rectangular shape. First tightening members **24** are provided at substantially central portions of two long sides extending in the direction indicated by the arrow B. Further, second tightening members **26** are provided at substantially central portions of two short sides extending in the direction indicated by the arrow C.

As shown in FIG. **3**, the unit cell **12** of the stack body **14** includes a membrane electrode assembly **28**, and a first separator **30** and a second separator **32** sandwiching the membrane electrode assembly **28**.

The membrane electrode assembly **28** includes a cathode **36**, an anode **38**, and a solid polymer electrolyte membrane (hereinafter simply referred to as the "electrolyte membrane") **34** interposed between the cathode **36** and the anode **38**. For example, the solid polymer electrolyte membrane **34** is formed by impregnating a thin membrane of perfluorosulfonic acid with water, for example. That is, the fuel cell stack **10** is so called a solid polymer electrolyte fuel cell.

Each of the cathode **36** and the anode **38** has a gas diffusion layer (not shown) of a carbon paper or the like facing the first separator **30** or the second separator **32**, and an electrode catalyst layer (not shown) interposed between each gas diffusion layer and the electrolyte membrane **34**. The cathode **36** and the anode **38** having such structure are known, and the detailed description of the cathode **36** and the anode **38** is omitted.

For example, the first separator **30** and the second separator **32**, sandwiching the membrane electrode assembly **28** as described above, include separator main bodies **30***m*, **32***m* which are made of metal plates such as steel plates, stainless steel plates, aluminum plates, plated steel sheets, or metal plates having anti-corrosive surfaces by surface treatment. It should be noted that the respective main bodies **30***m*, **32***m* of the first separator **30** and the second separator **32** may be made of carbon.

At one end of the unit cell **12** in the longitudinal direction indicated by the arrow B, an oxygen-containing gas supply passage **40** for supplying an oxygen-containing gas and a fuel gas supply passage **42** for supplying a fuel gas are provided. The oxygen-containing gas supply passage **40** and the fuel gas supply passage **42** extend through the unit cell **12** in the direction indicated by the arrow A. Further, at the other end of the unit cell **12**, a fuel gas discharge passage **46** for discharging the fuel gas and an oxygen-containing gas discharge passage **44** for discharging the oxygen-containing gas are provided. The fuel gas discharge passage **46** and the oxygen-containing gas discharge passage **44** extend through the unit cell **12** in the direction indicated by the arrow A.

At both ends of the unit cell **12** in the lateral direction indicated by the arrow C, two coolant supply passages **48** for supplying a coolant are provided oppositely on one side adjacent to the oxygen-containing gas supply passage **40** and the fuel gas supply passage **42**. Further, at both ends of the unit cell **12** in the lateral direction, two coolant discharge passages **50** for discharging the coolant are provided oppositely on the other side adjacent to the fuel gas discharge passage **46** and the oxygen-containing gas discharge passage **44**. The coolant supply passages **48** and the coolant discharge passages **50** extend through the unit cell **12** in the direction indicated by the arrow A.

Further, an oxygen-containing gas flow field **52** connected to the oxygen-containing gas supply passage **40** and the oxygen-containing gas discharge passage **44** is formed on an end surface **30***a* of the first separator **30** facing the membrane electrode assembly **28**. The oxygen-containing gas flow field **52** extends in the direction indicated by the arrow B.

Further, a fuel gas flow field **54** connected to the fuel gas supply passage **42** and the fuel gas discharge passage **46** is formed on an end surface **32***a* of the second separator **32** facing the membrane electrode assembly **28**. The fuel gas flow field **54** extends in the direction indicated by the arrow B.

The first separator **30** and the second separator **32** is formed by corrugating a metal thin plate having a rectangular surface by pressure forming to have a corrugated shape in cross section. This corrugation forms the oxygen-containing gas flow field **52** or the fuel gas flow field **54** in a wavy form.

Further, a coolant flow field **56** connected to the coolant supply passages **48** and the coolant discharge passages **50** are formed between an end surface **32***b* of the second separator **32** and an adjacent end surface **30***b* of the first separator **30**. The coolant can flow through the coolant flow field **56** over the range where the anode **38** or the cathode **36** is provided.

As the oxygen-containing gas, for example, air is adopted. As the fuel gas, for example, hydrogen or a hydrogen containing gas is adopted. Further, as the coolant, for example, water, organic solvent, or oil is used.

A first seal member **58** is formed integrally with the end surfaces **30***a*, **30***b* of the first separator **30**, around the outer end of the first separator **30**. A second seal member **60** is formed integrally with the end surfaces **32***a*, **32***b* of the second separator **32**, around the outer end of the second separator **32**. Each of the first seal member **58** and the second seal members **60** is made of seal material, cushion material, or packing material such as an EPDM (ethylene propylene diene monomer) rubber, an NBR (acrylonitrile butadiene) rubber, a fluorine compound rubber, a silicone rubber, a fluorosilicone rubber, a butyl rubber, a natural rubber, a styrene rubber, a chloroprene rubber, or an acrylic rubber.

Cutout portions **62***a*, **62***b* are formed in two long sides of the first separator **30** and the second separator **32**, respectively. The cutout portions **62***a*, **62***b* are elongated in the direction indicated by the arrow B. Projecting load receivers **64***a*, **64***b* are provided at substantially central positions of the cutout portions **62***a*, **62***b* in the direction indicated by the arrow B.

The projecting load receivers **64***a*, **64***b* are, e.g., made of resin material, and attached to the first separator **30** and the second separator **32**. That is, as shown in FIG. **4** where main components are enlarged, the projecting load receiver **64***a* includes a rectangular clip portion **66**, and the cutout portion **62***a* is partially inserted under pressure into, and joined to an insertion groove (not shown) formed in a lower end surface of the clip portion **66**.

The projecting load receiver **64***a* includes a projection **68** integrally attached to, and protruding from a central part of the clip portion **66**, as shown. The projection **68** is narrower than the clip portion **66**, and the load receiver **64***a* is attached to the separator main body **32***m* at the cutout portion **62***a*. The projection **68** includes an outer portion (head) **69** having a first diameter and including a horizontal top edge **68***e* which may extend slightly beyond the end surfaces of the long sides of the first separator **30** and the second separator **32** (where the cutout portions **62***a*, **62***b* are not present).

Further, the projection **68** also includes an intermediate, or "neck" portion **70** interconnecting the outer, head portion **69** and the clip portion **66**. The intermediate neck portion **70** has a second diameter at its narrowest part, which is smaller than the first diameter of the outer portion. The intermediate neck portion also has two first inner curves **70***a*, **70***b* formed at the sides thereof and depressed in the direction indicated by the arrow B in a semi-circular shape and formed adjacent to a proximal end of the projection **68**. This reduced-diameter intermediate neck portion permits significant bending of the projection **68**, as shown by the dotted-line outline in FIG. **4**, to accommodate small amounts of imperfect alignment of adjacent separators **30**, **32**, as needed. Since the first inner curves **70***a*, **70***b* are present, the rigidity of the intermediate portion **70** of the projection **68** is small in comparison with the case where the first inner curves **70***a*, **70***b* are not present in the projection **68**. Stated otherwise, the flexibility of the projection **68** is large, and the projection **68** is deformed easily when an external force (impact load) in the direction indicated by an arrow B1 is applied to the projection **68**, as shown by a virtual line (two-dot chain line).

The projecting load receiver **64***b* has the same structure as the projecting load receiver **64***a*. Therefore, the constituent elements of the projecting load receiver **64***b* that are identical to those of the projecting load receiver **64***a* are labeled with the same reference numerals, and descriptions thereof will be omitted. The projecting load receivers **64***a*, **64***b* may be provided at diagonal positions of the first separator **30** and the second separator **32**.

The projecting load receivers **64***a*, **64***b* are arranged in the stacking direction, and a plurality of the projecting load receivers **64***a* are jointly, and a plurality of the projecting load receivers **64***b* are jointly engaged with recessed engagement sections **72** of the respective first tightening members **24** (see FIG. **7**).

Short cutout portions **62***c*, **62***d* extending in the direction indicated by the arrow C are formed at substantially central positions of both of left and right ends of the two short sides of the first separator **30** and the second separator **32** (see FIG. **3**). Recessed load receivers **74***a*, **74***b* are inserted under pressure into, and joined to these cutout portions **62***c*, **62***d*. That is, the recessed load receiver **74***b* is provided between the oxygen-containing gas supply passage **40** and the fuel gas supply passage **42**, and the recessed load receiver **74***a* is provided between the oxygen-containing gas discharge passage **44** and the fuel gas discharge passage **46**. The ends of the recessed load receivers **74***a*, **74***b* in the direction indicated by the arrow B protrude slightly beyond the end surfaces of the short sides of the first separator **30** and the second separator **32**.

The recessed load receivers **74***a*, **74***b* also include respective clip portions **71**, which are respectively attached to the main bodies **30***m*, **32***m* of the corresponding separators **30**, **32** in a manner similar to that described above in connection with the clip portions **66** of the projecting load receivers **64***a*, **64***b*, and are also made of resin material as in the case of the projecting load receivers **64***a*, **64***b*. The recessed load receivers **74***a*, **74***b* are depressed inwardly at ends in the direction indicated by the arrow B to have first recesses **76**, which define first and second flange portions **73**, **75** extending outwardly from the clip portion **71** at opposite sides of the first recesses **76**, as shown. It should be noted that the electrolyte membrane **34** is also depressed to have second recesses **78**, at positions corresponding to the first recesses **76**.

As shown in FIG. **5** where main components are enlarged, each of the flange portions **73**, **75** adjacent the first recess **76** is depressed in a semi-circular shape to have two second inner curves **80***a*, **80***b* formed in the direction indicated by the arrow C. The flange portions **73**, **75** are substantially mirror images of one another, as shown, so only the detailed structure of the upper flange portion **73** will be described herein, with the understanding that the lower flange portion **75** is formed with a substantially similar structure. The upper flange portion **73** includes an outer portion (head) **73***h* having a first diameter and including a substantially flattened outer edge **73***e*. Further, the upper flange portion **73** also includes an intermediate, or "neck" portion **73***i* interconnecting the outer, head portion **73***h* and the clip portion **71**. The intermediate neck portion **73***i* has a second diameter at its narrowest part at a central portion of the inner curve **80***b*, which is smaller than the first diameter of the outer portion. The intermediate neck portion **73***i* also has the inner curve **80***b* formed at the side thereof and depressed to form a semi-circular shape adjacent to a proximal end of the upper flange portion **73**. This reduced-diameter intermediate neck portion permits significant bending of the upper flange portion **73**, as shown by the dotted-line outline in FIG. **5**, to accommodate small amounts of imperfect alignment of adjacent separators **30**, **32**, as needed. Since the second inner curves **80***a*, **80***b* are present, the rigidity of the recessed load receivers **74***a*, **74***b* is small in comparison with the case where the second inner curves **80***a*, **80***b* are not formed. That is, the flexibility of the recessed load receivers **74***a*, **74***b* is large, and the recessed load receivers **74***a*, **74***b* are deformed easily when an external force (impact load) in the direction indicated by the arrow C1 is applied to the ends of the recessed load receivers **74***a*, **74***b*, as shown by a virtual line in FIG. **5**.

The recessed load receivers **74***a* are arranged to have the same height in the stacking direction, and the recessed load receivers **74***b* are arranged to have the same height in the stacking direction. As described later, the recessed load receivers **74***a* and the recessed load receivers **74***b* are fitted to projecting engagement sections **82** of the second tightening members **26** (see FIG. **7**). The recessed load receivers **74***a*, **74***b* may be provided at respective diagonal positions of the first separator **30** and the second separator **32**.

Positioning holes **84***a*, **84***b* are provided at one of pairs of diagonal positions of the unit cells **12**, specifically, adjacent to an upper position of the fuel gas supply passage **42** and adjacent to an upper position of the oxygen-containing gas discharge passage **44**. As shown in FIGS. **2** and **6**, holes **86***a*, **86***b* are formed in the first end plate **20***a* and the second end plate **20***b*, coaxially with the positioning holes **84***a*, **84***b*.

Both ends of the positioning pin **88***a* having a columnar shape extending in the stacking direction are fitted into the holes **86***a* without any clearance, and both ends of the positioning pin **88***b* are fitted to the other holes **86***b* without any clearance. The positioning pins **88***a*, **88***b* are inserted into the positioning holes **84***a*, **84***b* with clearance. Preferably, the positioning pins **88***a*, **88***b* are made of SUS (stainless steel), aluminum, iron, resin such as PPS (Polyphenylenesulfide), carbon or the like.

As shown in FIG. **6**, each of the first tightening members **24** includes a plate shaped section **90***a* formed by extrusion, and attachment sections **92***a* fixed to both longitudinal ends of the plate shaped section **90***a*. For example, the plate shaped section **90***a* and the attachment sections **92***a* are welded together into one piece, or formed into one piece by cutting.

As shown in FIGS. **6** and **7**, the plate shaped section **90***a* has a corrugated shape in cross section, and includes a recessed engagement section **72**. The recessed engagement section **72** is engaged with the projecting load receivers **64***a* (**64***b*) of the unit cells **12**, and extends in the stacking direction. The outer surface of the first tightening member **24** is positioned inside the outer surface of the long side of the unit cells **12**. The plate shaped section **90***a* has recesses in the outer surface on both sides to achieve weight reduction. It should be noted that the recesses may not be formed so as to increase the bending strength of the plate shaped section **90***a*.

The attachment section **92***a* is thicker than the plate shaped section **90***a*, and two screw holes **94** and two positioning holes **96** are formed coaxially in the end surface of the attachment section **92***a* facing the first end plate **20***a* and the second end plate **20***b* (see FIG. **6**). Positioning rings **98** are fitted to the positioning holes **96**. Further, the positioning rings **98** are fitted to two holes **100** described later.

The two holes **100** are formed at central positions of each of the long sides of the first end plate **20***a* and the second end plate **20***b*. Bolts **102** are inserted into the holes **100** and the positioning rings **98**. Front ends of the bolts **102** are screwed to the screw holes **94**.

Each of the second tightening members **26** includes a plate shaped section **90***b* formed by extrusion, and attachment sections **92***b* fixed to both longitudinal ends of the plate shaped section **90***b*. For example, the plate shaped section **90***b* and the attachment sections **92***b* are welded together into one piece, or formed into one piece by cutting.

As shown in FIGS. **6** and **7**, the plate shaped section **90***b* has the projecting engagement section **82** extending in the stacking direction on a side surface facing the unit cells **12**. The projecting engagement section **82** is engaged with the recessed load receivers **74***a* (**74***b*) of the unit cells **12**. On the outside of the stacked components, the thickness of the second tightening member **26** is reduced as much as possible.

The attachment section **92***b* has the same structure as the attachment section **92***a* of the first tightening member **24** as described above. Therefore, the constituent elements of the attachment section **92***b* that are identical to those of the attachment section **92***a* of the first tightening member **24** are labeled with the same reference numerals, and descriptions thereof will be omitted.

Cushioning members **104***a* extending in the stacking direction are provided between the first tightening members **24** and the outer surface of the stack body **14**, and cushioning members **104***b* extending in the stacking direction are provided between the second tightening members **26** and the outer surface of the stack body **14**. The cushioning members **104***a*, **104***b* may be made of resilient material, such as epoxy resin. Alternatively, the cushioning members **104***a*, **104***b* may be made of the same material as the first seal member **58** and the second seal member **60**, such as silicone rubber. Further, material having heat resistance, weather resistance, chemical resistance, e.g., a formed rubber chiefly containing EPDM may be used for the cushioning members **104***a*, **104***b*.

The first tightening member **24** and the outer surface of the stack body **14** have a corrugated section including the recessed engagement section **72** and the projection **68** of the projecting load receiver **64***a* (**64***b*), which are engaged with each other. The cushioning member **104***a* is filled onto, or adhered onto the corrugated section without any clearance. A flange section is formed integrally with the cushioning member **104***a*, at both ends of a portion having a U-shape in cross section between the recessed engagement section **72** and the projecting load receiver **64***a* (**64***b*). The flange section is provided along a flat surface of the cutout portion **62***a* extending in a horizontal direction. The cushioning member **104***a* may be made of filling material. Alternatively, a plate shaped member may be used as the cushioning member **104***a*.

The second tightening member **26** and the outer surface of the stack body **14** have a corrugated section including the projecting engagement section **82** and the first recess **76** of the recessed load receiver **74***a* (**74***b*) and the second recess **78** of the electrolyte membrane **34**. The cushioning member **104***b* is filled onto, or adhered onto the corrugated section without any clearance. A flange section is formed integrally with the cushioning member **104***b*, at both ends of a portion having a

U-shape in cross section between the projecting engagement section **82** and the first recess **76** and the second recess **78**. The flange section is provided along a flat surface of the plate shaped section **90***b* extending in the vertical direction.

In the embodiment of the present invention, the total modulus of elasticity ST1 of the positioning pins **88***a*, **88***b* is larger than the modulus of elasticity ST2 of the single cushioning member **104***a*, and the modulus of elasticity ST2 of the single cushioning member **104***a* is larger than the modulus of elasticity ST3 of the single first tightening member **24** (ST1>ST2>ST3). Likewise the total modulus of elasticity ST1 of the positioning pins **88***a*, **88***b* is larger than the modulus of elasticity ST2 of the single cushioning member **104***b*, and the modulus of elasticity ST2 of the single cushioning member **104***b* is larger than the modulus of elasticity ST3 of the single second tightening member **26** (ST1>ST2>ST3).

As shown in FIG. **1**, the oxygen-containing gas supply passage **40**, the fuel gas supply passage **42**, the oxygen-containing gas discharge passage **44**, the fuel gas discharge passage **46**, the coolant supply passages **48**, and the coolant discharge passages **50** are formed in the first end plate **20***a*. Manifold members (not shown) are connected to the oxygen-containing gas supply passage **40**, the fuel gas supply passage **42**, the oxygen-containing gas discharge passage **44**, the fuel gas discharge passage **46**, the coolant supply passages **48**, and the coolant discharge passages **50**.

Alternatively, the oxygen-containing gas supply passage **40**, the fuel gas supply passage **42**, the oxygen-containing gas discharge passage **44**, and the fuel gas discharge passage **46**, may be formed in the first end plate **20***a*, and the coolant supply passages **48** and the coolant discharge passages **50** may be formed in the second end plate **20***b*.

The fuel cell stack **10** according to the embodiment of the present invention basically has the structure as described above. Next, operation and advantages of the fuel cell stack **10** will be described in conjunction with its operation.

For operation of the fuel cell stack **10**, firstly, as shown in FIG. **1**, at the first end plate **20***a*, a fuel gas is supplied to the fuel gas supply passage **42**, and an oxygen-containing gas is supplied to the oxygen-containing gas supply passage **40**. Further, further, a coolant such as pure water, ethylene glycol, or oil is supplied to the pair of the coolant supply passages **48**.

As shown in FIG. **3**, the fuel gas is supplied from the fuel gas supply passage **42** to the fuel gas flow field **54** of the second separator **32**. The fuel gas moves along the fuel gas flow field **54** in the direction indicated by the arrow B, and the fuel gas is supplied to the anode **38** of the membrane electrode assembly **28**.

At the anode **38**, hydrogen in the fuel gas is ionized to induce a reaction of producing protons. By proton conductive function of the electrolyte membrane **34**, the protons move toward the cathode **36**. Further, electrons are used as an electrical energy source for driving an external load electrically connected to the fuel cell stack **10**.

The oxygen-containing gas flows from the oxygen-containing gas supply passage **40** into the oxygen-containing gas flow field **52** of the first separator **30**. The oxygen-containing gas flows along the oxygen-containing gas flow field **52** in the direction indicated by the arrow B, and the oxygen-containing gas is supplied to the cathode **36** of the membrane electrode assembly **28**.

At the cathode **36**, oxygen in the oxygen-containing gas and the protons which have moved through the electrolyte membrane **34** and the electrons which have arrived at the cathode **36** after driving the external load induce reaction of producing water.

As described above, in the membrane electrode assembly **28**, the fuel gas supplied to the anode **38** and the oxygen-containing gas supplied to the cathode **36** are partially consumed in the electrochemical reactions for generating electricity.

The fuel gas partially consumed at the anode **38** is discharged along the fuel gas discharge passage **46** in the direction indicated by the arrow A. Further, the oxygen-containing gas partially consumed at the cathode **36** is discharged along the oxygen-containing gas discharge passage **44** in the direction indicated by the arrow A.

Further, the coolant supplied to the pair of coolant supply passages **48** flows into the coolant flow field **56** between the first separator **30** and the second separator **32**. After the coolant temporarily flows inward in the direction indicated by the arrow C, the coolant moves in the direction indicated by the arrow B for cooling the membrane electrode assembly **28**. After the coolant moves outward in the direction indicated by the arrow C, the coolant moves along the pair of coolant discharge passages **50**, and the coolant is discharged in the direction indicated by the arrow A.

During power generation operation as described above, impact loads may be applied to the fuel cell stack **10** from the outside, and the impact loads may include force components applied in the direction indicated by the arrow B1 or the direction indicated by the arrow C1, i.e., in a direction perpendicular to the stacking direction indicated by the arrow A.

For example, positional displacement of any of the projecting load receivers **64***a* (**64***b*) relative to the other projecting load receivers **64***a* (**64***b*) may occur, e.g., due to dimensional errors at the time of producing the first separator **30** and the second separator **32**, or variation in the positions of the stacked components at the time of assembling the fuel cell stack **10**. That is, as shown in FIG. **8**, the projection **68** of the projecting load receiver **64***a* (**64***b*) having the positional displacement protrudes beyond the projections **68** of the other projecting load receivers **64***a* (**64***b*). In FIG. **8**, for ease of understanding, the protruding degree is emphasized.

In this state, assuming that an impact load is applied to the first tightening member **24**, and as a result, the first tightening member **24** moves in the direction indicated by the arrow B1, the force in the direction indicated by the arrow B1 is firstly applied only to the projection **68** of the projecting load receiver **64***a* (**64***b*) which protrudes beyond the other projecting load receivers **64***a* (**64***b*). Stated otherwise, the force is locally concentrated on this projection **68**. Therefore, if the rigidity of the projection **68** is large and the projection **68** is not deformed significantly, the projecting load receiver **64***a* (**64***b*) subjected to concentration of the force may be damaged undesirably.

However, in an attempt to address the problem, as shown in FIG. **4**, the first inner curves **70***a*, **70***b* are formed adjacent to the proximal end of the projection **68** to provide sufficient flexibility of the projection **68**. Therefore, as shown by the virtual line in FIG. **4**, the projection **68** to which the force is applied firstly is deformed easily. As a result, this projection **68** is placed in alignment with the other projections **68**.

Therefore, thereafter, the force is received by a plurality of the projections **68** that are placed in alignment with one another. Thus, the force is not concentrated on the single projection **68**, but distributed. Since the force applied to each of the projections **68** becomes less than the withstand load of the projecting load receiver **64***a* (**64***b*), it becomes possible to avoid damages of the projecting load receivers **64***a* (**64***b*).

Also in the recessed load receivers **74***a* (**74***b*), positional displacement of any of the recessed load receivers **74***a* (**74***b*) relative to the other recessed load receivers **74***a* (**74***b*) may occur, e.g., due to dimensional errors at the time of producing the first separator **30** and the second separator **32**, or variation in the positions of the stacked components at the time of assembling the fuel cell stack **10**. That is, as shown in FIG. **9**, the end of the recessed load receiver **74***a* (**74***b*) having the positional displacement protrudes beyond the ends of the other recessed load receivers **74***a* (**74***b*). In FIG. **9**, for ease of understanding, the protruding degree is emphasized.

In this state, assuming that an impact load is applied to the second tightening member **26**, and as a result, the second tightening member **26** moves in the direction indicated by the arrow C1, the force in the direction indicated by the arrow C1 is firstly applied only to the end of the recessed load receiver **74***a* (**74***b*) which protrudes beyond the other recessed load receivers **74***a* (**74***b*). Stated otherwise, the force is locally concentrated on this end.

In this regard, in the embodiment of the present invention, as shown in FIG. **5**, the second inner curves **80***a*, **80***b* extending to the first recess **76** are formed to provide sufficient flexibility of the recessed load receivers **74***a* (**74***b*). Therefore, as shown by a virtual line in FIG. **5**, the recessed load receiver **74***a* (**74***b*) to which the force is applied firstly is deformed easily. As a result, the end of this recessed load receiver **74***a* (**74***b*) is placed in alignment with the ends of the other recessed load receivers **74***a* (**74***b*).

Therefore, thereafter, the force is received by a plurality of the ends that are placed in alignment with one another. Thus, the force is not concentrated on the single recessed load receiver **74***a* (**74***b*), but distributed. Since the force applied to each of the ends becomes less than the withstand load of the recessed load receiver **74***a* (**74***b*), it becomes possible to avoid damages of the recessed load receivers **74***a* (**74***b*).

After all, in the embodiment of the present invention, the first inner curves **70***a*, **70***b* are formed in the projecting load receivers **64***a* (**64***b*), and the second inner curves **80***a*, **80***b* are formed in the recessed load receivers **74***a* (**74***b*) to increase flexibility of the projecting load receivers **64***a* (**64***b*) and the recessed load receivers **74***a* (**74***b*). Thus, even if variation in the positions of the stacked components is present between the plurality of projecting load receivers **64***a* (**64***b*) and/or between the plurality of recessed load receivers **74***a* (**74***b*), upon application of the force, the projecting load receives **64***a* (**64***b*) are placed in alignment with one another, and the recessed load receivers **74***a* (**74***b*) are placed in alignment with one another. Thus, it is possible to prevent concentration of the force on the projecting load receiver **64***a* (**64***b*) or the recessed load receiver **74***a* (**74***b*) having large positional displacement in comparison with the others, and it is possible to avoid the resulting damages of the projecting load receivers **64***a* (**64***b*) and the recessed load receivers **74***a* (**74***b*).

Further, in the embodiment of the present invention, the total modulus of elasticity ST1 of the positioning pins **88***a*, **88***b* is larger than the modulus of elasticity ST2 of the single cushioning member **104***a*, and the modulus of elasticity ST2 of the single cushioning member **104***a* is larger than the modulus of elasticity ST3 of the single first tightening member **24** (ST1>ST2>ST3). Likewise the total modulus of elasticity ST1 of the positioning pins **88***a*, **88***b* is larger than the modulus of elasticity ST2 of the single cushioning member **104***b*, and the modulus of elasticity ST2 of the single cushioning member **104***b* is larger than the modulus of elasticity ST3 of the single second tightening member **26** (ST1>ST2>ST3).

Therefore, curves of the positioning pins **88***a*, **88***b* can be absorbed by the cushioning members **104***a*, **104***b*, and it becomes possible to maintain the desired compression force applied to the cushioning members **104***a*, **104***b* by the first tightening members **24** and the second tightening members **26**.

Thus, with simple and compact structure, it is possible to prevent positional displacement of the stacked unit cells **12**, and suppress damages of the positioning pins **88***a*, **88***b* as much as possible.

In FIGS. **4** and **5**, the first inner curves **70***a*, **70***b* and the second inner curves **80***a*, **80***b* are shown as cutouts in a semi-circular shape (i.e., the radius of curvature is constant). Alternatively, the radius of curvature on the side adjacent to the first separator **30** or the second separator **32** may be different from the radius of curvature on the side away from the first separator **30** or the second separator **32**. Hereinafter, an embodiment regarding this structure will be described.

FIG. **10** is a front view schematically showing a projecting load receiver **112** provided in the first separator **30** as a whole. The projecting load receiver **112** has first inner curves **110***a*, **110***b*. In this case, the radius of curvature of the first inner curves **110***a*, **110***b* is large on a side adjacent to the first separator **30**, and small on a side away from the first separator **30**.

More specifically, in the first inner curve **110***a*, a virtual circle C1 having a radius of r1 contacts a first curved portion **118** at the proximal end of a projection **114** (adjacent to the border between the projection **114** and a clip portion **116**), and a virtual circle C2 having a radius of r2 contacts a second curved portion **120** at a wide front end of the projection **114**. The radius r1 is larger than the radius r2 (r1>r2). Though not shown, the first inner curve **110***b* has the same structure. It is a matter of course that the projecting load receiver **112** may be provided in the second separator **32**.

When a load is applied to the projecting load receiver **112** having the structure as described above, since the first inner curves **110***a*, **110***b* are formed such that the radius of curvature of the second curved portion **120** becomes smaller than the radius of curvature of the first curved portion **118**, stress concentration tends to occur adjacent to the second curved portion **120**, i.e., at the front end of the projection **114**. Therefore, when the stress applied to the projecting load receiver **112** becomes excessive, cracks extending from the second curved portion **120** of the first inner curve **110***a* to the second curved portion **120** of the first inner curve **110***b* tend to be formed easily.

As a result, the projecting load receiver **112** is damaged firstly from its front end, and the clip portion **116** is not damaged easily. Therefore, it is possible to avoid exposure of the first separator **30** (or the second separator **32**) through the clip portion **116**.

In the structure, it is possible to avoid formation of an electrically conductive channel through the exposed position of the first separator **30**, and thus, it is possible to maintain the desired insulating performance at the position covered by the clip portion **116**.

The present invention is not limited to the above described particular embodiments, and various modifications can be made to the embodiments without departing from the gist of the invention.

For example, in the embodiments, the stack body **14** is formed by stacking the unit cells **12** each comprising a solid polymer electrolyte fuel cell. Alternatively, the stack body **14** may be formed by stacking unit cells each comprising a solid oxide fuel cell.

Further, as for the load receivers, only the projecting load receivers **64***a*, **64***b* may be provided, or only the recessed load receivers **74***a*, **74***b* may be provided.

What is claimed is:

**1**. A fuel cell stack formed by stacking a plurality of unit cells, the unit cells each including an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly, the electrolyte electrode assembly including an anode, a cathode, and an electrolyte interposed between the anode and the cathode,

wherein the separator includes a separator main body formed from a first material and a load receiver formed from a second material which is different from the first material, the load receiver attached to the separator main body for receiving a load in a direction perpendicular to a stacking direction of the unit cells;

the load receiver is made of a flexibly resilient resin, and has either a projection protruding outwardly from an outer portion of the separator main body or a recess depressed inwardly from the outer portion of the separator main body; and

the load receiver includes a clip portion for attaching to the separator main body, an outer portion having a first diameter and an intermediate portion interconnecting the outer portion and the clip portion, the intermediate portion having a second diameter which is smaller than the first diameter;

wherein the intermediate portion includes a curved edge portion which is depressed to form an inner curve, and the inner curve of the load receiver provides flexibility in a direction perpendicular to the stacking direction.

**2**. The fuel cell stack according to claim **1**, wherein a tightening member extending in the stacking direction to support the unit cells is engaged with at least one of the projection and the recess of the load receiver.

**3**. The fuel cell stack according to claim **1**, wherein, in the case where the load receiver has the projection, radius of curvature of the inner curve is large on a side adjacent to the separator main body, and small on a side proximate the outer portion and away from the separator main body.

**4**. A fuel cell stack formed by stacking a plurality of unit cells, the unit cells each including an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly, the electrolyte electrode assembly including an anode, a cathode, and an electrolyte interposed between the anode and the cathode,

wherein the separator includes a separator main body and a load receiver attached to the separator main body for receiving a load in a direction perpendicular to a stacking direction of the unit cells;

the load receiver is made of a flexibly resilient resin, and comprises a clip portion attached to the separator main body and a projection protruding outwardly from the clip portion, the projection including a head portion having a first diameter and a neck portion interconnecting the head portion and the clip portion, the neck portion having a second diameter which is smaller than the first diameter; and

the neck portion is formed with an inner curve on each of two sides thereof, and the inner curve of the neck portion provides flexibility of the head portion in a direction perpendicular to the stacking direction.

**5**. A fuel cell stack formed by stacking a plurality of unit cells, the unit cells each including an electrolyte electrode assembly and a pair of separators sandwiching the electrolyte electrode assembly, the electrolyte electrode assembly including an anode, a cathode, and an electrolyte interposed between the anode and the cathode,

wherein the separator includes a separator main body formed from a first material, and first and second load receivers formed from a flexibly resilient resin material which is different from the first material, the first and second load receivers attached to the separator main body for receiving a load in a direction perpendicular to a stacking direction of the unit cells;

the first and second load receivers are made of a flexibly resilient resin, and the first load receiver has a projection protruding outwardly from an outer portion of the separator main body, and the second load receiver defines a recess depressed inwardly from the outer portion of the separator main body; and

each of the first and second load receivers includes a clip portion for attaching to the separator main body, an outer portion having a first diameter and an intermediate portion interconnecting the outer portion and the clip portion, the intermediate portion having a second diameter which is smaller than the first diameter;

wherein the intermediate portion includes a curved edge portion which is depressed to form an inner curve, and the inner curve of the load receiver provides flexibility in a direction perpendicular to the stacking direction.

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